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Sandia National Laboratories
Waste Isolation Pilot Plant

Analysis Plan for the Impact Assessment of Alternate Panel Closure Systems

AP-087

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1 INTRODUCTION AND OBJECTIVES

In May of 1998 the Environmental Protection Agency (EPA) issued its final rule on the certification of the Waste Isolation Pilot Plant (WIPP). EPA certified WIPP's compliance with 40 CFR Part 194 subject to specific conditions, the first of which mandated the design of the panel closure system (PCS). In its Compliance Certification Application (CCA), the Department of Energy (DOE) presented four options for the design of the PCS, but did not specify which one would be constructed at the WIPP. As stated in the EPA ruling, "The EPA based its certification decision on the condition that DOE implement the most robust design (referred to in the CCA as "Option D"). The Agency found the Option D design to be adequate, but also determined that the use of a Salado Mass Concrete – using brine rather than fresh water – would produce concrete seal permeabilities in the repository more consistent with the values used in DOE's performance assessment. Therefore, Condition 1 of EPA's certification requires DOE to implement the Option D PCS at the WIPP, with Salado Mass Concrete." (EPA, 1998a)

DOE is proposing to modify the design of the PCS for reasons of cost and operational efficiency. In support of that proposal, DOE tasked Sandia National Laboratories (SNL) to assess the long-term impact of alternate panel closure systems on the performance of the WIPP. This document describes our approach to conducting the requested assessment.

As directed by DOE, SNL will conduct a series of compliance calculations, using the EPA-approved WIPP performance assessment (PA) models, which will characterize the potential impact of a variety of PCS designs on repository performance. For this analysis we will not consider changes to conceptual models for the repository, as such changes would require peer review as a prerequisite for acceptance by EPA. We will use the mandated Option D PCS as the baseline for identifying impacts on performance. Due to the uncertainty in the final design of the PCS, an analysis that characterizes the impact on performance of a variety of PCS designs will be more useful than detailed modeling of a specific design.

This analysis may not contain sufficient detail to determine the effects of varying panel closure characteristics on repository performance. Analysis of detailed features such as the panel closures requires an appropriate level of resolution in the computational grid. At the time of the CCA and the PAVT, the specific panel closure design was not known; consequently, the panel closures were modeled generically in those calculations. The baseline grid for those calculations was appropriate for the generic panel closures that were modeled. However, the baseline panel closure for this impact assessment must be the Option D panel closure design. The baseline grid is not sufficiently detailed to represent the specific features of this panel closure design. Consequently, in this analysis we will employ an effective permeability approach to represent implicitly the specific features of the Option D panel closure design in the baseline grid.

We will support this analysis with results from the recently completed Technical Baseline Migration (TBM) calculations. The TBM evaluates the effects of a number of corrections and improvements to the WIPP PA system (Lord and Hadgu, 2002). One of these improvements is a detailed representation of the Option D PCS. The TBM is intended to advance the technical baseline for compliance assessments, and thus requires review and approval by the EPA. The EPA's review and approval process entails considerable time and resources and has not been completed; hence the TBM cannot take the place of the accepted technical baseline. However, the WIPP Quality Assurance program allows, and sound scientific practices require consideration of all information pertinent to a performance assessment. We believe that the TBM calculation provides insight into the potential effects of the panel closures on repository performance. Hence, we will use the TBM to assist in understanding and evaluating the assumptions and results of this analysis.

2 APPROACH

Our analytic approach focuses on the representation of panel closures in the calculation of two-phase flow in and around the repository. The most significant mechanism for releases from the repository is a drilling intrusion. The releases from a drilling intrusion are primarily determined by the pressure and brine saturation in the waste regions at the time of the intrusion. Both pressure and brine saturation are calculated by the PA model for two-phase flow in and around the repository, implemented in the BRAGFLO code. Hence, it is essential to accurately represent the effects of the PCS on brine and gas flow in the BRAGFLO model.

The spectrum of potential PCS designs can be represented by varying the effective permeability of the PCS and the adjoining materials. The baseline case with the mandated Option D panel closure represents the less permeable end of the spectrum, as will be described later in this document. We will use results from the CCA and the PAVT to represent the more permeable end of the spectrum.

Neither the CCA nor PAVT modeled the specifics of the Option D PCS. In the CCA, the PCS was represented as a homogeneous material (PAN_SEAL) with a constant permeability of 1.0×10^{-15} m^2 with a large, surrounding DRZ of the same permeability (DOE, 1996). In the PAVT, the DRZ permeability around the PCS was changed to a loguniform distribution varying between 3.16×10^{-13} m^2 to 3.98×10^{-20} m^2. The PCS permeability remained at 1.0×10^{-15} m^2, providing a relatively easy path for brine and gas to move across the PCS (EPA, 1998b). Consequently, we do not believe that the CCA and PAVT calculations illustrate the effects of the less permeable panel closures, such as the Option D PCS.

We will modify the PAVT parameters to represent an Option D PCS in place of the original PCS. Using the modified parameter values, we will use BRAGFLO to calculate the effects on pressure and saturation due to the Option D PCS in the E0, E1, E2 and E1E2 scenarios. A single replicate will be run, using the random seed from the PAVT R1 replicate, so that results from each calculation can be compared on a vector-by-vector basis.

In addition to comparison of pressures and brine saturations calculated with BRAGFLO, we will complete a full set of PA calculations for the PAVT with Option D PCS to produce complementary cumulative distribution functions (CCDFs) of releases. We will compare these CCDFs with the CCDFs from the PAVT and CCA calculations to identify any impacts on long-term releases from the repository due to PCS characteristics.

2.1 Option D Panel Closure in the Baseline Grid.

In the baseline grid, panel closures are represented by a single column of cells with width either 40 m or 80 m.[1] These cells are assigned a single material, PAN_SEAL. The Option D panel closures have two distinct components, a concrete monolith that is 7.9 m thick, and an adjacent drift containing an explosion wall that is 32.1 m in depth. In the TBM we modified the grid to explicitly represent the panel closure components in two columns of cells. In order to represent the Option D PCS in the baseline grid with a single column of cells, we calculate the permeability, porosity and initial brine saturation for the material PAN_SEAL based on the explicit geometry and material assignments in the TBM representation. All other properties of the material PAN_SEAL remain the same as for the PAVT calculation.

Figure 1 shows the detailed representation of the Option D PCS used in the TBM grid and the representation we will use in the baseline grid. Table 1 summarizes the materials used to represent the panel closures and the adjacent material in the repository in the several calculations. Figure 2 shows the baseline grid. Figure 3 shows the TBM grid.

1 In the baseline grid, the cells representing the northern PCS are 80 m in the X-direction. This closure represented a double set of closures that are planned.

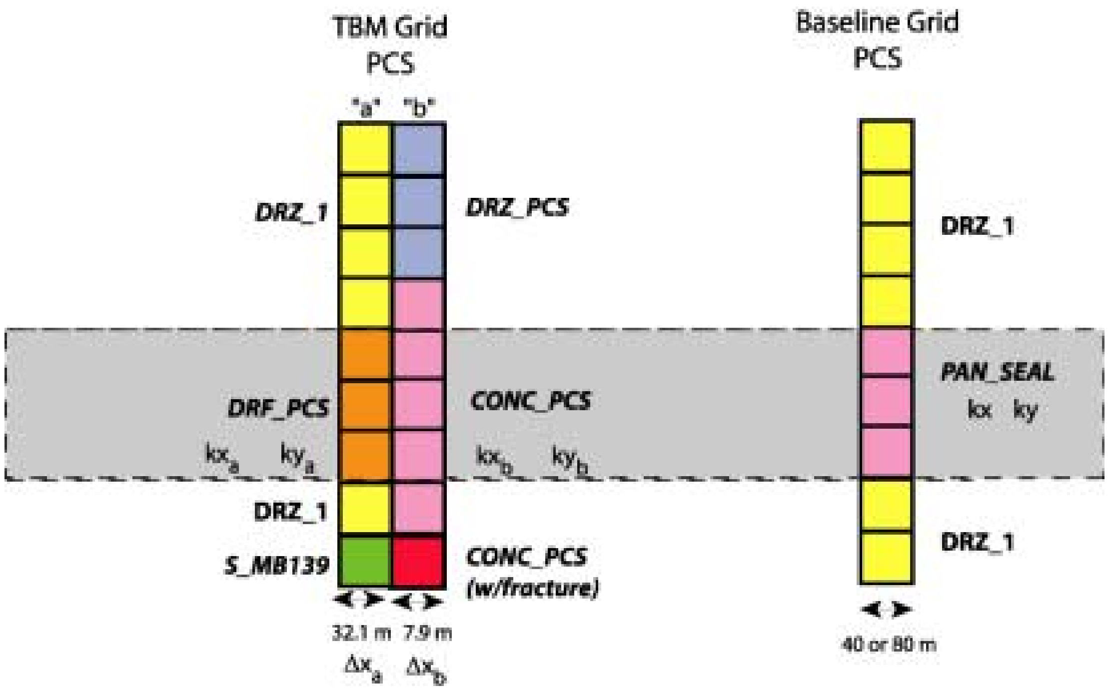


Figure 1. PCS Representation in TBM and Baseline Grids

Table 1. Materials used to represent panel closure systems.

Material	CCA and PAVT	TBM	PCS Impact Assessment
PAN_SEAL	Represents a generic PCS filling the drift	Not used Replaced by CONC_PCS and DRF_PCS	Represents PCS filling the drift; properties derived from CONC_PCS and DRF_PCS
CONC_PCS	Not used	Represents the concrete monolith of the Option D PCS	Not used
DRF_PCS	Not used	Represents the empty drift and explosion wall for the Option D PCS	Not used
DRZ_PCS	Not used	Represents the healed DRZ above the concrete monolith	Not used
DRZ_1	Represents the DRZ above and below the excavated areas	Represents the DRZ above and below the excavated areas except for the DRZ above the concrete monolith	Represents the DRZ above and below the excavated areas, including above and below the concrete monolith

Figure 2. Baseline Grid with Option D PCS.

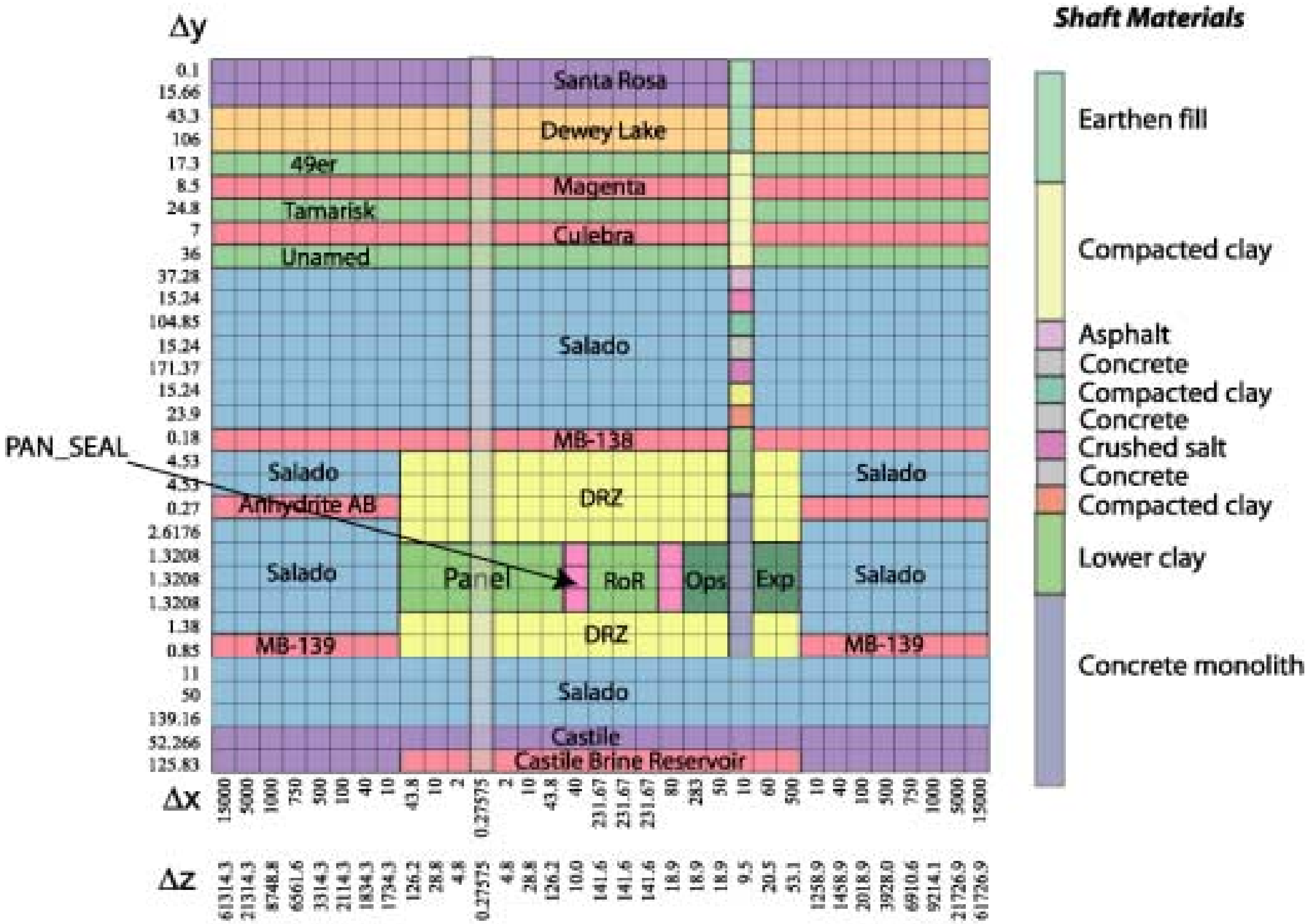
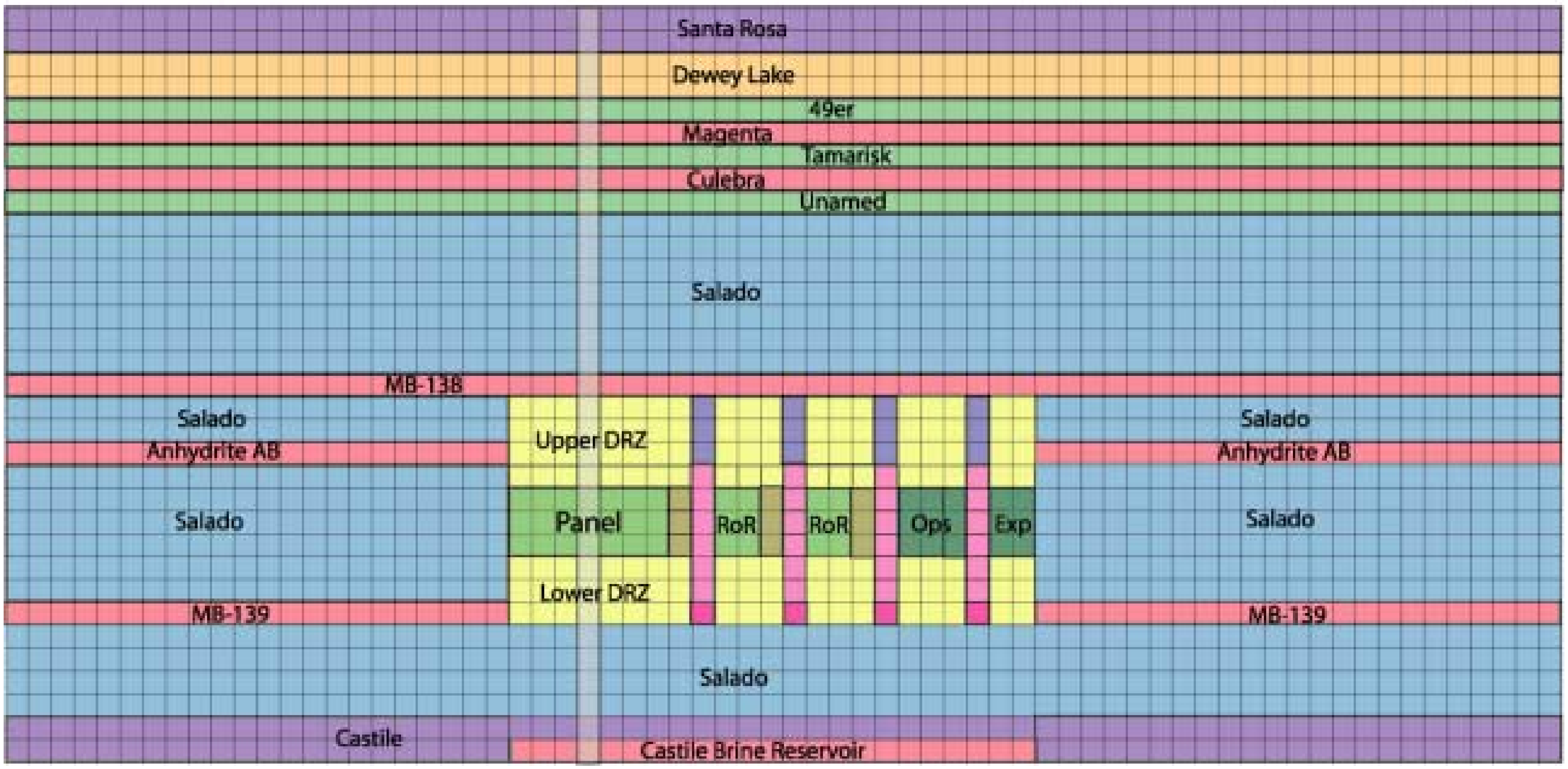


Figure 3. Technical Baseline Migration (TBM) Grid.



The TBM explicitly modeled the Option D PCS by applying three distinct materials to two columns of cells: CONC_PCS, representing the concrete monolith; DRF_PCS, representing the drift adjacent to the monolith and the explosion wall; and DRZ_PCS, representing the healed DRZ above the rigid monolith. The concrete monolith extends down to the bottom of Marker Bed 139. To capture the potential for pressure-induced fracturing in Marker Bed 139 around the PCS, in the TBM we assigned fracture properties to the bottom cell of the monolith that match the surrounding marker bed.

In the baseline grid, panel closures comprise a single column of cells to which we assign two materials, PAN_SEAL and DRZ_1. The material PAN_SEAL represents the combination of the concrete monolith, the adjacent drift and the explosion wall emplaced in the drift. To represent this combination, we assign to PAN_SEAL, the properties that were used in the PAVT calculation for the generic panel closure, with exceptions for permeability, porosity, and initial brine saturation.

The material DRZ_1 represents the combination of the panel closure components and the surrounding halite above and below the drift. Since we do not allow changes to repository conceptual models for this analysis, the DRZ above the monolith is not assumed to heal; in contrast, in the TBM representation the material DRZ_PCS was assumed to heal. Hence, we assign to DRZ_1 the same properties as were assigned to the DRZ surrounding the repository in the PAVT.

2.2 Permeability of Material PAN_SEAL

For the material PAN_SEAL, we calculate effective permeability values in the X- and Y- directions from the component materials of the corresponding cells in the TBM grid. The effective permeability in the X-direction can be expressed as the X-length-weighted harmonic mean of the permeability of CONC_PCS and DRF_PCS because flow in X is normal to the interface between materials. The formulation of the permeability in the X-direction is thus:

$$kx = \frac{kx_a kx_b (\Delta x_a + \Delta x_b)}{\Delta x_a kx_b + \Delta x_b kx_a} \tag{1}$$

where kx_a and kx_b are the X components of permeability and Δx_a and Δx_b are the X-dimensions (Figure 1).

The effective permeability in the Y-direction parallel to their interface can be expressed as the X-length-weighted mean of the Y-components of permeability,

$$ky = \frac{ky_a \Delta x_a + ky_b \Delta x_b}{\Delta x_a + \Delta x_b} \tag{2}$$

2.2.1 *Permeability of Panel Closure Concrete (CONC_PCS)*

The EPA required Option D and the use of Salado Mass Concrete (SMC) as conditions of their rule (EPA, 1998a). Furthermore, the DOE must use salt-saturated concrete in the PCS, as was specified for the shaft seal system. Material parameters for SMC in the shaft seal system elements are summarized in Hurtado et al. (1997). The permeability of the SMC seal components was treated as a random variable defined by a log triangular distribution with a mode of 1.78 x 10^{-19} m^2 and lower and upper limits of 2.0 x 10^{-21} and 1.0 x 10^{-17} m^2, respectively. In this analysis we will model the permeability of the concrete in the panel closures as a constant and will use the mode of SMC permeability distribution.

The CCA assumed that cementitious materials would degrade after 400 years. However, a subsequent and more detailed evaluation (Thompson and Hansen, 1996) concluded that no significant degradation is expected for the concrete members of the panel closure concrete. They showed that potential flow through the concrete closure is nearly two orders of magnitude too small to cause any significant degradation. Consequently, in this analysis we assume that the PCS concrete does not degrade over time.

2.2.2 Permeability of Panel Closure Drift (DRF_PCS)

To represent the drift and explosion wall for the TBM we used the material DRF_PCS. This material is assigned properties equal to the neighboring regions, WAS_AREA and OPS_AREA, including their creep-closure behavior. For the present calculations of effective permeability we will assume the material DRF_PCS has equivalent permeability to WAS_AREA (2.4 x 10^{-13} m^2).

2.2.3 Effective Permeability of Option D PCS

Using the permeabilities for the concrete and drift portions of the PCS, we calculate the effective permeability the PCS to be 9.01 x 10^{-19} m^2 in the X-direction and 1.93 x 10^{-13} m^2 in the Y-direction. These values are the same for the 40 m and 80 m panel closures in the baseline grid, since the 80 m panel closure represents two sequential 40 m panel closures.

2.3 Porosity of Material PAN_SEAL

The porosity of the panel closure is the pore volume divided by the total volume. For this analysis, we assign to the material PAN_SEAL the volume-weighted average porosity for the CONC_PCS and the DRF_PCS materials. The porosity of the material CONC_PCS was set at 0.05. In the TBM, two values were used for the porosity of the material DRF_PCS. Where DRF_PCS was adjacent to waste-filled regions, the creep closure model dynamically determined the porosity of DRF_PCS. Elsewhere, the porosity of the DRF_PCS was assigned a value of 0.18, representing the porosity of void space after creep closure has stopped. In this analysis, we use the value of 0.18 for the porosity of adjacent drift, resulting in a porosity value for PAN_SEAL of 0.15.

2.4 Initial Brine Saturation of Material PAN_SEAL

The initial brine saturation for PAN_SEAL is calculated as the volume-weighted average of the initial brine saturations for the CONC_PCS and DRF_PCS materials. The initial brine saturation for CONC_PCS was set at 0.99; for DRF_PCS, the initial brine saturation was 0.015. The initial brine saturation for the material PAN_SEAL is thus 0.21.

3 SOFTWARE LIST

The major codes to be used for these calculations are listed in Table 2. Calculations will be performed on the ES-40 DEC ALPHA running Open VMS Version 7.2-1.

Table 2. Codes to be used in the panel closure impact assessment.

Code	Version
ALGEBRACDB	2.35
BRAGFLO	4.10
CCDFGF	3.01
CUTTINGS_S	5.04
GENMESH	6.08
ICSET	2.22
LHS	2.41
MATSET	9.00
NUTS	2.05
PANEL	3.60
POSTBRAG	4.00
POSTLHS	4.07
PREBRAG	6.00

PRELHS	2.10
SUMMARIZE	2.20

4 TASKS

The schedule, tasks, and responsible individuals are outlined in Table 3.

Table 3. Tasks and responsibilities.

Date	**Task(s)**	**Responsible Individual**
May 31 – June 15, 2002	Prepare Input Files	Cliff Hansen
June 15 – July 1, 2002	BRAGFLO Calculations	Cliff Hansen Rodger Coman
July 15	Deliver Report on BRAGFLO calculations	Cliff Hansen
July 1 – July 21, 2002	Calculate CCDFs	Cliff Hansen Jim Garner Rodger Coman
August 15, 2002	Deliver Impact Assessment	Cliff Hansen

5 SPECIAL CONSIDERATIONS

None.

6 APPLICABLE PROCEDURES

Analyses will be conducted in accordance with the quality assurance (QA) procedures listed below.

Training: Training will be performed in accordance with the requirements in NP 2-1, Qualification and Training.

Parameter Development and Database Management: Selection and documentation of parameter values will follow NP 9-2. The database will be managed in accordance with relevant technical procedure.

Computer Codes: New or revised computer codes that will be used in the analyses will be qualified in accordance with NP 19-1. All other codes unchanged since the PAVT are qualified under multi-use provisions of NP 19-1. Codes will be run on the Compaq Alpha using Open VMS AXP, Version 7.2-1.

Analysis and Documentation: Documentation will meet the applicable requirements in NP 9-1.

Reviews: Reviews will be conducted and documented in accordance with NP 6-1 and NP 9-1, as appropriate.

7 REFERENCES

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